Clayton Falls Water Use Plan:
Monitoring Program Terms of Reference:
Aquatic Productivity

July 11, 2005

1.0 Monitoring Program Rationale

1.1 Background

The Consultative Committee (CC) for the Clayton Falls Water Use Plan (WUP) expressed concern that the lack of a guaranteed base flow in the mainstem channel between Clayton Falls and the confluence of the tailrace channel might affect the overwinter survival of fish and their invertebrate prey. To address this concern, the CC recommended that the WUP include a 0.05_m3•s-1 minimum continuous flow release from the Clayton Falls Dam. Because of uncertainty regarding the benefits of this flow release to fish and their invertebrate prey, the CC also recommended that a monitoring program to assess the ecological response to the new flow regime. This document describes the terms of reference for this monitoring program.

The Clayton Falls Project is a run-of-river facility. Water is diverted from the creek above Clayton Falls, passed through the powerhouse and into the tailrace channel. Flows from the tailrace re-join lower Clayton Falls Creek and flow a short distance to the ocean. Anon (2003) contains a more detailed description. For the purposes of this program, Clayton Falls Creek has been divided into the following three sections:

a) Lower Clayton Falls Creek Reach 1: from the confluence of the powerhouse tailrace downstream to the estuary

b) Lower Clayton Falls Creek Reach 2: from the base of the Falls downstream to the confluence with the powerhouse tailrace (Reach 2 is 83 m long)

c) Upper Clayton Falls Creek: unregulated section upstream of the headpond

During the low flow period from December to March, normal operation of the facility diverts most of the inflows to the generating station. As a result, flows to Reach 2 are limited largely to minimal dam leakage and local inflows (estimated at ~0.05 m3•s-1), as well as periodic spills. The proposed 0.05 m3•s-1 minimum continuous flow will increase winter flows in Reach 2 to at least 0.1 m3•s-1.

Lower Clayton Falls Creek provides high quality rearing habitat for juvenile Dolly Varden (*Salvelinus malma*), rainbow trout/steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), and sculpin (*Cottus* sp.). Occasional periods of very low or no flow could affect the suitability and availability of these habitats, as well as the survival of fish and their invertebrate food sources. These effects would be realized in Reach 2, where dam releases may be the only reliable source of flow. Conversely, flows in Reach 1 are little affected by facility operations; operations only affect whether the tailrace channel or Reach 2 supplies most of the flow to Reach 1. The period of lowest flows occurs from February to March and habitat de-watering in Reach 2 during this period can occur, though its extent and duration are uncertain. Because fish and many invertebrates generally overwinter in the interstitial spaces provided by cobbles and boulders during this period, dewatering of these habitats could reduce available habitat or cause stranding mortality, and hence have an overall impact on fish and invertebrate populations. Invertebrate rearing and survival during the winter are important as many aquatic invertebrate species have multi-year lifecycles and benthic invertebrates are active during the winter.

The CC recommended that a minimum flow be provided to increase the overwinter survival of fish and invertebrate populations in lower Clayton Falls Creek by maximizing effective habitat for rainbow trout parr (>1 year old) and improving habitat conditions for their invertebrate food supply. Available aquatic information is limited and only confirms the presence of fish in Reach 2. Therefore, the minimum flow release will not begin until one year after approval of the WUP to facilitate the collection of pre-flow release data that is needed to test hypotheses about the benefits of the flow release. Subsequent monitoring during the treatment flow would demonstrate the benefits of providing the continuous year-round flow to Reach 2. Monitoring results will help to inform future operating decisions and are expected to provide the rationale for the minimum flow release.

This monitoring program was developed based on the proposal approved by Consultative Committee (see Appendix F of Anon 2003). Modifications to the original proposal are listed in Appendix A, which includes the rationale for all changes.

1.2 Management Questions

The fundamental goal of the monitoring program is to reduce uncertainty related to the expected ecological benefits of a minimum flow release from Clayton Falls Dam year-round. As such, the primary management question is:

> How does the minimum flow alter the physical conditions of habitats in Reach 2 and, in turn, influence the community composition and productivity of invertebrates and fish?

1.3 Detailed Hypotheses about the Ecological Impacts of Operational Change

Hypothesis 1 Existing productivity in Reach 2

The first hypothesis relates to the pre-WUP conditions in Reach 2.

H1: Pre-WUP flows in Reach 2 (dam leakage and local inflows) are sufficient to sustain over-wintering fish and invertebrates.

Hypothesis 1 addresses the assumption held during the WUP process that habitat conditions (as they are affected by flow) during the winter limit the productivity of fish and invertebrate populations in Reach 2. Hence, current low winter flows have had a significant negative effect on fish population density, and invertebrate density and community structure (i.e., aquatic ecological productivity is significantly different from the unregulated state).

Hypothesis 2 Productive capacity in Reach 2

The primary ecological hypothesis[1] to be tested is:

H2: The provision of a year round minimum base flow of 0.1 m3•s-1 to Reach 2 (0.05 m3•s-1 from the dam release and an anticipated 0.05 m3•s-1 from dam

1 For clarity, hypotheses are stated as alternate hypotheses. Analyses will test the null hypothesis of no effect or difference.

leakage and natural inflow) will partially restore the productive capacity of lower Clayton Falls Creek. Productive capacity will primarily be measured as the standing crop biomass of salmonids sampled during the fall.

This hypothesis reflects the view that higher flows in Reach 2 during the winter will provide a gain in wetted habitat area, ensure that riffle habitats are wetted continuously, and improve overwinter conditions for juvenile salmonids.

This primary hypothesis will be tested using three components: invertebrate abundance, invertebrate community diversity, and salmonid standing crop (Figure 1). Salmonid standing crop (biomass per unit wetted stream area) will be the primary indicator of productive capacity because it integrates the effects of flow on trophic productivity and habitat conditions. However, changes in salmonid standing crop will likely be small and difficult to detect statistically. In addition, fish abundance can vary in response to factors unrelated to stream discharge, (i.e., spawner abundance, predation). For instance, fish that rear in R2 are likely recruited from spawning in R1 and the tailrace, and the response of the fish population to the minimum flow is contingent on there being sufficient spawning habitat in R1 and the tailrace to ensure spawning success. Concerns over available spawning gravel were raised during the WUP (Anon 2003). Therefore, changes in the secondary indicators—invertebrate abundance and diversity—will be used in a weight of evidence approach to provide additional inferential power and a better insight into the ecological linkages in the stream.

Hypothesis 3 Invertebrate abundance

H3: The flow release will increase invertebrate abundance.

Hypothesis 4 Invertebrate community diversity

H4: The flow release will increase the diversity of the invertebrate community.

Hypothesis 5 Salmonid standing crop

H5: The flow release will increase salmonid standing crop.

- H5a: The flow release will increase salmonid density.
- H5b: The flow release will increase salmonid size.
- H5c: The flow release will increase salmonid condition.

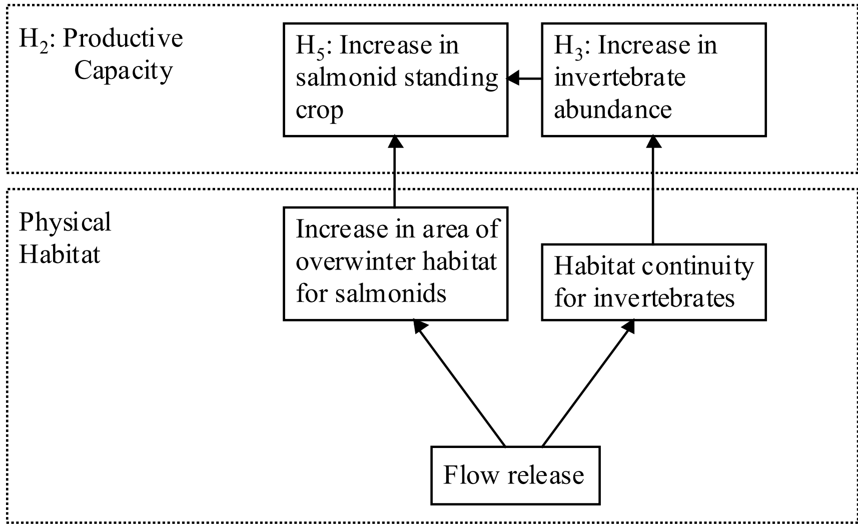

Figure 1: Hypothesized Relationships between the Flow Release, Physical Habitat and the Productive Capacity of Lower Clayton Falls Creek

1.4 Key Water Use Decision Affected

The water use decision affected by the results of the monitoring program is the magnitude of the minimum flow release from Clayton Falls Dam into lower Clayton Falls Creek. Results of the monitoring program are expected to support the scientific rationale for selecting a long-term flow regime at Clayton Falls. This decision has implications for ecological and power generating values. Lower Clayton Falls Creek is viewed as providing high quality rearing habitat for salmon, char and steelhead, and opportunities to improve productivity in the creek are highly valued. Alternatively, releasing water from the dam will increase the volume of diesel fuel required to generate an equivalent amount of energy at the Ah-Sin-Heek diesel plant to compensate for the decrease in annual generation at the Clayton Falls plant (see Section 7 of Anon 2003).

2.0 Monitoring Program Proposal

2.1 Objective and Scope

The key objective of the monitoring program is to assess the ecological benefits of the proposed flow release and to collect the information needed to help inform future decisions. The monitoring program will focus on the benefits to Reach 2. To help make inferences about changes in Reach 2, the program will include a control site in Reach 1 and another site in upper Clayton Falls Creek, for a total of three sites. The program will run for 4 years.

2.2 Approach

The proposed monitoring program has three components.

1) Collect ecological information on salmonid abundance, invertebrate abundance, and invertebrate species diversity both prior to (1 year) and during (3 years) the flow release.

2) Assess changes in these measures pre and post flow release.
3) Compare the salmonid abundance in reaches of Clayton Falls Creek with data from nearby, unregulated systems to assess the adequacy of changes and help to distinguish between natural variation and the effects of flow releases. Since the biological response is likely to be small and, therefore, difficult to detect statistically, the approach uses standard sampling protocols to allow comparisons with reference systems.

The minimum flow release is expected to benefit biota during the winter. These benefits will be inferred from biological sampling during the low flow period in the late summer/early fall.

2.3 Methods

Field sampling will measure physical habitat and estimate fish and invertebrate abundance and species diversity. Table 1 summarizes the three components of the field sampling program and each component is described briefly below.

Table 1: Monitoring components, measurement variables, and sampling requirements for the Clayton Falls Water Use Plan monitoring program

Monitoring Component	Measurement Variable	Number of Sites
1. Invertebrate abundance	Abundance per basket	2
2. Invertebrate community diversity	Relative abundance by taxa	2
3. Salmonid standing crop	Abundance and biomass per m^2	3

2.3.1 Task 1. Invertebrate Abundance

The density of benthic invertebrates will be sampled to provide an index of secondary productivity. One site in Reach 2 and a control site in upper Clayton Falls Creek will be sampled. Colonization baskets will be used for sampling because they are well suited for studies that examine changes over time (Anon 1997). Baskets will be set following the methods in Anon (1997) with 6 baskets per site. Invertebrate samples will be sorted and counted in the lab. While the estimated budget only allows for four baskets per site to be sorted in the lab (Table 2), six baskets per site will be set in case there are opportunities to sort more baskets in the lab and to allow for possible basket losses in the field. For each basket, total invertebrate density and density by taxa will be calculated.

2.3.2 Task 2: Invertebrate Community Diversity

Taxonomic data from Task 1 will be used to calculate relative abundance by taxa. Changes in the relative abundance of those taxa most commonly consumed by fish will be of primary interest.

2.3.3 Task 3: Salmonid Standing Crop

Estimates of salmonid standing crop will be obtained from multiple pass electrofishing and, where feasible, verified with snorkel counts. All captured fish will be measured, weighed and identified to species. Stomach contents from 10 juvenile Dolly Varden per year will be collected and analyzed to determine the key invertebrate food sources consumed.

At each site, crews will measure the standard habitat descriptions used for provincial steelhead inventory work as described in Bech (1994) (e.g., substrate, conductivity). Crews will also measure hydraulic conditions (depth and velocity) at 2 transects per site. Stream discharge and stage (where possible) will be collected at each site. Records of discharge will also be obtained from operators at Clayton Falls Dam to provide an indication of flow conditions throughout the year prior to monitoring.

Salmonid density and biomass per m2 wetted area will be calculated for each species and age class. To adjust for differences in habitat suitability among sites and among years, fish density per 100 m2 wetted usable area will also be calculated using depth and velocity profiles measured at transects, and habitat suitability indices for *O. mykiss*, Dolly Varden and coho (available from Ron Ptolemy). The adjusted densities for each species and age class are expressed as ‘adjusted fish per unit’ (FPU). The theoretical maximum adjusted FPU that Clayton Falls Creek could support will be estimated using a regression model based on total alkalinity that was derived from other streams in BC (Ptolemy 1993). When adjusted FPU is expressed as a percent of the estimated maximum adjusted FPU, it provides a measure of the status of the fish population and can be compared with values from neighbouring streams.

Dolly Varden are likely a self-sustaining, resident population and may serve as a good indicator species for monitoring; unlike coho and steelhead, Dolly Varden are not affected by rearing conditions in the ocean and are also likely present at the control site in upper Clayton Falls Creek.

To help distinguish between natural variation in fish biomass over time and the effects of the flow release, data may be compared with *O. mykiss* parr density estimates from comparable reaches in neighbouring, unregulated streams (e.g., Nusatsum River, Sawmill River). This comparison will also help to determine the adequacy of changes that do occur. For example, if current fish abundance in Reach 2 is similar to that from comparable habitats in streams that have similar hydraulic conditions, increased winter flows would not be expected to greatly increase abundance. It is anticipated that a program lead by the Ministry of Water, Land and Air Protection (WLAP) will sample these reference systems concurrently. Annual reports for these Terms of Reference (described below) will summarize or provide a reference for these data from nearby streams.

2.3.4 Task 4: Collate discharge records

Discharge records will be obtained from BC Hydro for use in subsequent analyses.

2.3.5 Task 5: Data entry

All data will be entered into a Microsoft Access database.

2.3.6 Task 6: Reporting

A brief, summary data report will be prepared annually that summarizes the methods employed, and fish and invertebrate abundance. The report will include will include a summary of data collected by WLAP from nearby streams.

At the conclusion of monitoring, a final report will be compiled which will include:

(a) an executive summary of the entire project;

(b) methods employed;

(c) a data summary as described for the annual data reports;

(d) a comparison of results among years;

(e) a detailed summary of the findings as they relate to the ecological hypotheses and the key management questions; and

(f) any recommendations towards (i) modifying the minimum flow to benefit aquatic production; and (ii) future monitoring (if any) needed to determine the response to the 0.05 m3•s-1 minimum flow release from the dam.

Reports will follow the standard format that is being developed for WUP monitoring programs. All reports will be provided in hard-copy and as Microsoft Word and Adobe Acrobat (*.pdf) format and all maps and figures will be provided in their native format either as embedded objects in the Word file or as separate files.

2.4 Interpretation of Monitoring Program Results

The flow release will be judged to have partially restored the productive capacity of lower Clayton Falls Creek if there is an increase in salmonid standing crop or invertebrate abundance. However, statistical inferences on these changes will likely be weak. For example, the statistical power to detect changes in invertebrate abundance is low given the large variability inherent in invertebrate sampling and the expected small effect size. A statistical power analysis with a Before-After Control-Impact design, 4 baskets per site, and a type I error of 0.05 suggests that there is likely only an 18% chance of correctly detecting a 50% increase in invertebrate abundance in Reach 2. Therefore, results from each component of the monitoring program as well as data from neighbouring streams will be evaluated in a weight of evidence approach to support expert judgment on the benefits of the flow release.

Changes in salmonid standing crop and adjusted FPU in Reach 2 will be compared with changes in upper Clayton Falls Creek and neighbouring streams. Relative values will also be compared with data from neighbouring streams. For example, standing crop and adjusted FPU in Reach 2 can be evaluated to determine whether values exceed a given percentile relative to other streams (i.e., values are above or below the 50th percentile of streams).

The CC recommended that a technical review of the monitoring results be undertaken by BC Hydro, appropriate government agencies, First Nations, and interested parties at the completion of the five year monitoring program.

2.5 Schedule

Monitoring is scheduled for 1 year prior to flow releases and 3 years post release, for a total of 4 years. Sampling will occur annually during the low flow period in the fall. A key uncertainty that could prevent data collection is the occurrence of high flow events from fall storms. Such events have prevented sampling attempts in previous years (R. Ptolemy, WLAP, personal communication). If such delays occur, sampling will likely be postponed until conditions are suitable.

2.6 Budget

The estimated budget for the monitoring program is $42,680 without inflation (Table 2). Costs are estimated in 2005 dollars and total inflation costs are included on the second to last line of Table 2. The estimate assumes that some cost efficiencies will be gained by coordinating the sampling with concurrent sampling by WLAP near Bella Coola. The estimate assumes that local technicians are used and includes an extra trip in the first year for crew training and site selection. Charge rates are based on typical consultant rates.

Table 2: Estimated costs for the Clayton Falls monitoring program. Contingency and administration are calculated on field labour, and cover safety planning, travel time, regulatory approvals (permits), field management, and unforeseen weather delays. Year 1 is the pre-treatment (flow release) sampling.

Task	**Labour**	Units					
		Daily rate	Yr 1	Yr 2	Yr 3	Yr 4	Total Cost
Site selection	Biologist	$500	1				$500
Set colonization	Technician 1	$300	1	1	1	1	$1,200
baskets	Technician 2	$300	1	1	1	1	$1,200
Retrieve baskets	Biologist	$500	0.5	0.5	0.5	0.5	$1,000
	Technician 1	$300	0.5	0.5	0.5	0.5	$600
	Technician 2	$300	0.5	0.5	0.5	0.5	$600
Fish and habitat	Biologist	$500	1.5	1.5	1.5	1.5	$3,000
	Technician 1	$300	1.5	1.5	1.5	1.5	$1,800
	Technician 2	$300	1.5	1.5	1.5	1.5	$1,800
Travel	Biologist	$500	2	1	1	1	$2,500
Data entry	Technician	$300	1	1	1	1	$1,200
Reporting	Biologist	$500	2	1	1	3	$3,500
	Technician	$300	1	1	1	2	$1,500
	Contingency	5%	$215	$165	$165	$165	$710
	Admin	10%	$430	$330	$330	$330	$1,420
						Subtotal	*$22,530*
	Expenses	Cost					
	Air fare	$550	2	1	1	1	$2,750
	Accommodation	$100	3	3	3	3	$1,200
	Meals	$50	4	4	4	4	$800
	Vehicle	$100	4	3	3	3	$1,300
	Fuel	$50	4	3	3	3	$650
	Colonization baskets	$15	12				$180
	Weigh scale	$170	1				$170
	Invert taxonomic analysis	$325	8	8	8	8	$10,400
	Fish collection permit	$25	1	1	1	1	$100
	Supplies (field) [a]	$200	2	1	1	1	$1,000
	Stomach content analysis	$25	10	10	10	10	$1,000
	Report production	$100	1	1	1	3	$600
						Subtotal	*$20,150*
	Inflation	2%	$0	$191	$387	$678	$1,256
		Total	**$12,470**	**$9,761**	**$9,957**	**$11,748**	**$43,936**

[a] Includes stationary, a tape measure, and the rental of a flow meter, electrofisher, conductivity meter and stop nets.

References

Anon 2003. Consultative committee report: Clayton Falls water use plan. Prepared for and by the Consultative Committee for the Clayton Falls Water Use Plan.

Anon 1997. Freshwater biological sampling manual. Published by the British Columbia Resource Information Committee. Available online: http://srmwww.gov.bc.ca/risc/pubs/aquatic/index.htm.

Bech, P. 1994. Lower Mainland Region Stream Inventory/Assessment Methods. Unpublished Manuscript LM 229. Ministry of Environment, Lands and Parks. Surrey, BC.

Ptolemy, R. A. 1993. Maximum salmonid densities in fluvial habitats in British Columbia. Proceedings of the 1992 Coho Salmon Workshop, Nanaimo, B.C.

Appendix A: Modifications from the initial proposal presented in Appendix F of Anon (2003)

This monitoring program is based on the proposal approved by Consultative Committee (see Appendix F of Anon 2003). Table A1 summarizes modifications that were made to ensure that the all tasks outlined for the monitoring program were accounted for in the budget.

Table A1: Modifications in the current Terms of Reference relative to the original study proposal

Item	Original Proposal	Current Terms of Reference
Additional trip in year 1	Labour not included	Labour included
Weekly flow measurements at colonization baskets	In methods, not budgeted	Excluded
Drift and nutrient samples	In methods, not in budget	Excluded
Office labout rate		Increased to reflect consultant rates
Contingency and administration		Included explicitly (15%)
Total estimated cost	$40,786[a]	$42,680[b]

[a] Costs from the original proposal were adjusted from 2002 dollars ($38,100) to 2005 dollars using an inflation rate[2] of 7.05%

[b] Costs listed for the current Terms of Reference do not include inflation over the 4-year study

2 http://www.bankofcanada.ca/en/inflation_calc.htm